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A Conceptual Framework for the Evaluation of Coastal Habitats

by Gary L. Ray
Environmental Laboratory

WES

Prepared for Headquarters, U.S. Army Corps of Engineers

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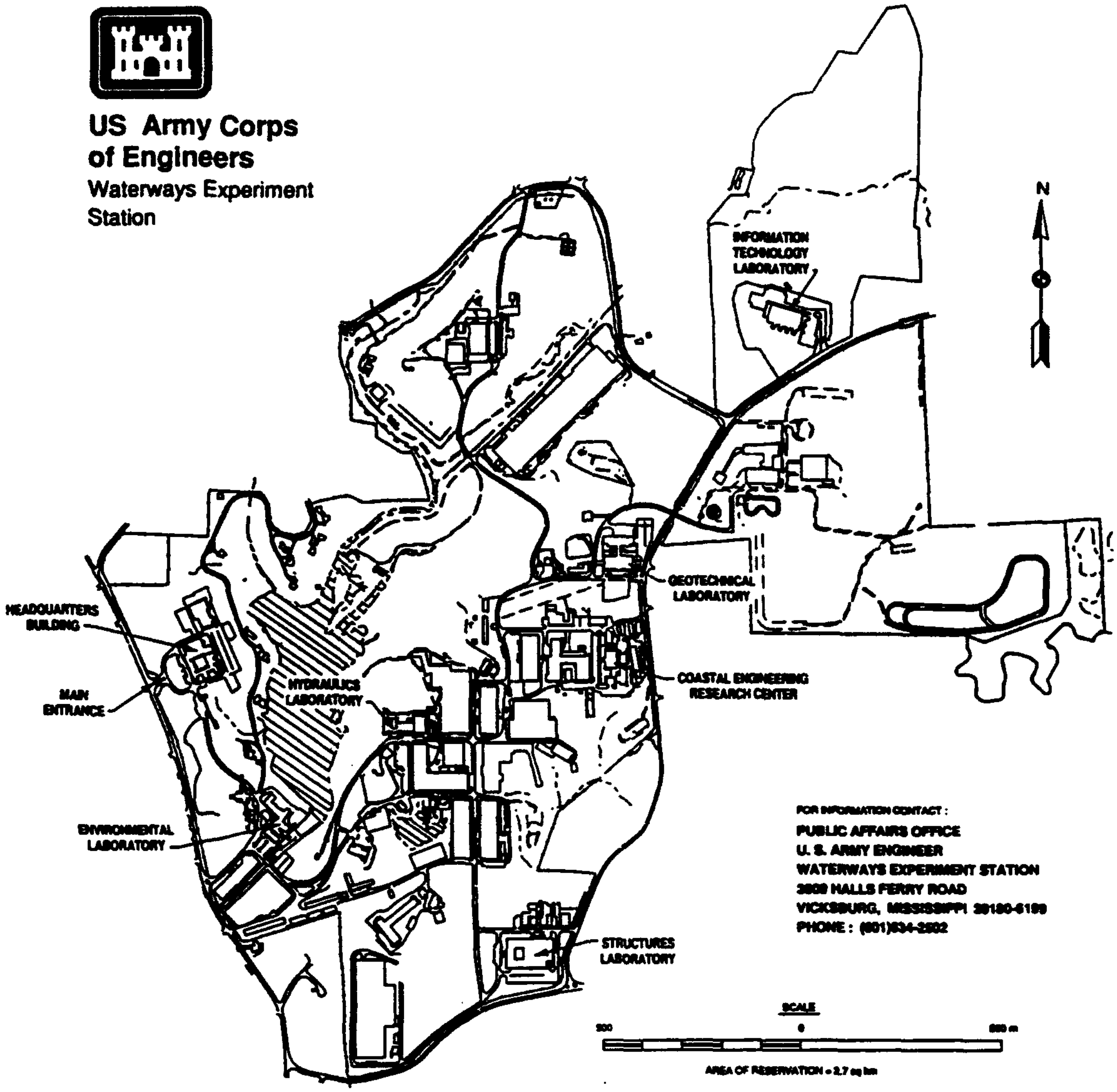

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Contents

Preface

This report was prepared by the Ecological Research Division (ERD), Environmental Laboratory (EL), U.S. Army Engineer Waterways Experiment Station (WES), as part of the Environmental Impact Research Program (EIRP), sponsored by Headquarters, U.S. Army Corps of Engineers (HQUSACE). Technical monitors were Dr. John Bushman and Mr. Frederick B. Juhle, HQUSACE. Dr. Roger T. Saucier, EL, WES, was EIRP Program Manager.

The framework is the result of the collaborative efforts of a multidisciplinary working group that included Marcia Bowen (Normadeau Associates, New Bedford, NH), Dr. Robert Diaz (Virginia Institute of Marine Sciences, Glouster Point, VA), Dr. Courtney T. Hackney (Breedlove, Dennis & Associates, Orlando, FL), Dr. Mark LaSalle (Mississippi State University Coastal Research and Extension Service, Biloxi, MS), Dr. Nancy Rabalais (Louisiana Universities Marine Consortium, Chauvin, LA), Mr. Charles Simenstad (Fisheries Research Institute, University of Washington, Seattle, WA), and Dr. Douglas Clarke (WES).

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1 Introduction

Problem Statement

Mitigation for damage to estuarine and marine habitats by engineering projects often involves habitat restoration or replacement. Such activities generally require the sacrifice of a different habitat type. For instance, an oyster bed might be constructed by placement of shell (cultch) on nearby unvegetated substrates. In this case, the unvegetated substrate habitat is traded for oyster-bed habitat. At other times, it may be impossible or impractical to construct or restore the original habitat type, and an "out-of-kind" habitat is constructed. In the previous example, a seagrass bed might be constructed in lieu of oyster-bed habitat.

Evaluating the environmental impact of habitat "trade-offs" involves comparison of both constructed or restored sites with natural habitats (e.g., a constructed oyster bed versus a natural oyster bed) and disparate habitat types (e.g., oyster beds, grass beds, and unvegetated substrates). At first glance, such an analysis appears to be a classic case of comparing "apples and oranges." Downing (1991) explored this analogy and noted that apples, oranges, and any other set of objects (including habitats and ecosystems) can be meaningfully compared if common features are examined. In the case of habitats or ecosystems, comparisons can be made using structural characteristics and ecological functions or attributes.

The biological structures characteristic of a habitat are the communities that make it up (Table 1). The ecological attributes are those functions provided by the habitat to the ecosystem as a whole (e.g., primary productivity and predation refuges). A seagrass habitat can be used as an example; it consists of rooted vascular plants, epiflora (diatoms and other flora that live on the grass blades), sediment microflora (mostly diatoms), epifauna (e.g., amphipods), infauna (e.g., polychaetes), and fish and invertebrate populations that spend part or all of their lives in the grassbed. The attributes provided by this habitat include primary productivity of the seagrass and other floral communities and secondary productivity of the faunal communities. The seagrass blades serve as substrate for attachment for sedentary species and for placement of eggs by motile species. The physical structure of the bed also provides a refuge from predation for many organisms at different points in their life histories.

An evaluation technique specifically designed to compare different habitats should measure a wide diversity of structures and functional attributes (LaSalle and Ray 1992). Measurement of primary production in the seagrass bed discussed above can be used as an example of the complexity of this problem. Sources of primary production include vascular plants, algae, and diatoms. Each of these sources is associated with various structures in the environment (e.g., sediment, rocks, and vascular plant stems or leaves) and requires separate evaluation. The productivity of each source will ultimately produce different quantities and qualities of food material for consumer species. Productivity of each source will also vary according to the location of the habitat within an individual coastal system and over the habitat's geographical range. Bowen and Small (1992) reviewed evaluation techniques available for coastal habitats and concluded that existing methods are inadequate. Methods such as the Wetland Evaluation Technique (WET) (Adamus and Stockwell 1983; Adamus et al. 1987; Diaz 1982) and Benthic Resources Assessment Technique (Lunz and Kendall 1982) cannot be applied to all habitats and do not measure all important functional attributes. Likewise, the Habitat Evaluation Procedure (HEP) (U.S. Fish and Wildlife Service (USFWS) 1980) relies on Habitat Suitability Index models that have been difficult to devise for coastal species (Nelson 1987). The Biological Evaluation Standardized Technique (BEST) (MEC Analytical Systems, Inc. 1988) suffers from being driven by individual species requirements rather than habitat attributes. These techniques are also inadequate to evaluate the contribution individual habitats make to the functioning of other habitats in the ecosystem.

Individual habitats do not exist in isolation, but are interdependent parts of coastal ecosystems. For instance, seagrasses not only support habitat-specific flora and fauna, but also export detritus, which is used as food by other communities. Likewise, coastal organisms move freely from one habitat to the next to satisfy their life history requirements for shelter, feeding, reproduction, and development. Habitat trade-offs result in a change in both the areal extent of certain habitats and the relative proportions of habitat types present in a system. While the impact of an individual trade-off is generally minimal, a series of trade-offs occurring over a number of years or in concert with impacts from other sources (e.g., changes in land-use patterns) can result in a significant change in the nature of a system. The depletion of wetlands in heavily industrialized estuaries is an extreme example of such a situation. While the importance of assessing the cumulative impact of changes in the amounts and proportions of habitats in a system is generally recognized, existing evaluation methods do not deal with these problems. If the issue of habitat trade-offs is to be meaningfully addressed, new techniques need to be devised. A conceptual framework for one such technique is presented in this document. It was suggested by a working group of estuarine scientists and has been briefly described in LaSalle and Ray (1992).

A Conceptual Framework

As with any evaluative method, a new habitat comparison technique needs to be quantitative, repeatable, flexible, understandable on technical and non-technical levels, accurate, and cost-effective (Diaz 1982; Bowen and Small 1992). A technique designed specifically to evaluate habitat trade-offs must additionally examine a broad range of structural and functional attributes, compare values for these attributes with those expected in the appropriate geographic region, and provide a mechanism for interpreting changes in these attributes on a system-wide basis. Comparisons should also be made on a system-by-system basis because each watershed, estuary, or coastline is characterized by a unique combination of geological, morphological, hydrodynamic, and meteorological features. These elements interact to determine the basic types, area, and quality of habitats that are present at any given time. It is assumed that each coastal system will potentially support a particular range of habitats in system-specific proportions and, therefore, must be analyzed individually.

The framework described in this document is essentially an inventory and accounting procedure that utilizes habitat attributes as basic input. Habitats in a system (e.g., estuary, watershed, and area of coastline) are mapped and their areas measured. Their structural and functional attributes are then listed, and an estimate is made of the extent to which each habitat attains the value expected for that region of the country. For instance, the benthic algal primary productivity of a specific mud flat in Virginia may only achieve 75 percent of what is normal for that region while another mud flat in the same system may realize 100 percent of the expected productivity. These percentages are then multiplied by the area of the habitat to arrive at a habitat/attribute value. If the first mud flat has an area of 50 ha, its habitat/attribute value would be 0.75 times 50 or 37.5 units. If the area of the second mud flat is also 50 ha, it would have a value of 1.00 times 50 or 50 units. This process is repeated for each habitat-attribute combination, and values for identical habitats are summed. In the previous example, the total mud flat benthic primary productivity value for that system would be 87.5 units. The 87.5-unit value can then be compared with estimates of historical conditions to evaluate how the system has changed, or used as a baseline for with-project and without-project comparisons.

At this point, it is important for the reader to recognize that the framework described in this document is still in a formative stage. Many of its underlying assumptions have not been rigorously tested, and case studies are just getting underway. Enhancement and refinement of the basic procedure will be required as the validity of the underlying assumptions are examined and practical experience is gained.

In subsequent sections, the steps necessary to perform the analysis are discussed and demonstrated using a hypothetical system. The procedure itself can be broken down into 10 steps (Table 2). The first step is to define the boundaries of the system under study. Next, background information on the system is collected and compiled. The background information itself consists of two types: data necessary for an understanding of the general nature of the system (e.g., hydrodynamics and meterology), and data used directly in the analysis (e.g., estimates of primary production by seagrasses and fisheries utilization of benthic invertebrates). Habitats present in the system are identified (Step 3) along with their critical attributes (Step 4). Fifth, the average attribute values expected in that region of the country are established from literature sources. Sixth, habitats are mapped and the area of each habitat type is measured. Seventh, an estimate or direct measure of each attribute (e.g., mud flat benthic invertebrate production) is then made and compared with the regional average. So that these values are understandable by nonexperts, the attribute is expressed as a percentage of the regional average (Step 8). Ninth, as previously described, the attribute value is multiplied by the area of the habitat to produce a value that represents the total amount of a particular attribute that is supplied to the system. Finally, the total amount of each habitat's attributes are compared for different time periods (e.g., historical versus present conditions) or different scenarios (e.g., with and without project conditions).

The advantage of this framework is that it clearly identifies probable losses and gains because of changes in the habitats in a system. The tendency to equate innately different attribute types (seagrass primary production versus salt marsh primary production) is avoided because each attribute is identified as a separate entity.

The framework uses both qualitative (habitat type) and quantitative (habitat attribute) data and should be cost-effective in that much of the raw data for the calculations is already available from the technical literature or government publications. The calculations are simple enough to be performed with virtually any computer spreadsheet program. The procedure is flexible since it is independent of the types of habitats or environmental status (e.g., polluted and pristine) of the system to which it is applied. It is also "upgradable" in the sense that as new information is obtained, it can be entered into the calculations with minimal effort. The results of the calculations are sufficiently intuitive to be understood on the nontechnical level, yet provide adequate information for making technically based decisions. Also, the results provide information for the decision-making process but do not drive that process. This problem is inherent in species-based evaluation methods such as HEP or BEST, where the choice of target species injects bias.

The combination of a system-wide and system-by-system analysis makes this approach fundamentally different from the current practice of project-specific analysis. The new framework will require a substantial change from current approaches to evaluating impacts to habitats. Under the project-specific approach, a relatively small amount of information is evaluated during a project, but the entire process must be repeated every time there is a new project. This repetition results in a considerable amount of wasted time and effort. In addition, changes in personnel or simply the passage of time can lead to inconsistent results by application of different standards. The system-wide approach requires that a broad-based and long-term perspective be taken towards project evaluations. The assembly of background data, mapping of habitats, and assignment of expected attribute values for an entire system will not be a trival effort. The initial investment, however, should be repaid by eliminating the repetition of effort associated with the project-specific approach. Finally, decision-making processes will be improved, because the choices inherent in implementing the framework (e.g., the initial choice of critical attributes and the assessment of what changes in these variables may imply) require a consensus among decision-makers regarding the importance of specific attributes, the environmental status of the system, and the ultimate environmental goals for the system.

2 Framework for a Coastal Habitat Evaluation Method

Step 1. Identifying System Boundaries

The first step in the framework is to establish the boundaries of the system to be studied (Table 2). Upland limits are the maximum extent of the watershed or drainage basin. In large systems, multiple watersheds may be involved. The upland limits are not used directly in subsequent analyses, but provide a logical boundary for assessing the character and environmental status of the system. For instance, knowledge of land-use patterns in upland areas (e.g., industrial or urban development, agricultural practices, and natural upland habitats) is needed to understand potential sources of disturbance (e.g., point or nonpoint pollution sources). Coastal watershed and drainage basin boundaries have been mapped in most areas of the country and can be found in the National Oceanographic and Atmospheric Administration (NOAA) National Estuarine Inventory Data Atlas (NOAA 1985) or the United States Geological Survey's Hydrological Unit Maps. The National Estuarine Inventory maps also include basic data on total surface area, area of salinity zones, drainage basin shape, freshwater inflow rates, prevailing tides, tidal ranges, position of tide gauges, and cross-sectional topographic profiles.

Boundaries for the delineation of habitats in the system are the terrestrial, aquatic, and seaward limits. The terrestrial limit is the uppermost extent of the intertidal zone and can be determined from surface elevations and tidal ranges or from vegetational patterns. NOAA is presently mapping the coastal marshes of the United States, and these maps will be the most efficient source of information since it will be possible to simultaneously determine the terrestrial boundary and marsh and intertidal habitat areas. The aquatic limit is the maximum extent of tidal influence in associated rivers and can be deduced from tidal charts or vegetation patterns. Establishing the seaward boundary of a system is more problematic. Few precise boundaries analogous to the watershed exist, and those that do (e.g., the limits of the Continental Slope), do not impose a physical barrier to the exchange of material, energy, or organisms. Geographic variation also makes generalization difficult. The difficulty in defining the seaward boundary makes it necessary to arbitrarily define it as the maximum extent of estuarine influence. This boundary obviously limits initial applications to estuaries. However, this is a reasonable restriction since most trade-offs involve estuarine habitats. Appropriate boundaries for purely marine or marine-estuarine systems will be developed at a later time.

To illustrate the identification of boundaries and all subsequent steps, a hypothetical system, "Anywhere Bay," will be analyzed. A map of the bay is presented in Figure 1. Upland limits of the system are indicated by the watershed. The landward system boundary was estimated from aerial photographs, and the seaward limits were derived from a National Estuarine Inventory Map. The system is comprised of nine different habitat types occurring in various amounts (Table 3). Figure 2 presents the distribution of each habitat type. The example scenario is that a development is planned in the upper reaches of the estuary. Approximately 800 ha of oligohaline marsh will be directly eliminated and 100 ha of polyhaline seagrass planted on previously unvegetated sands as mitigation. Figure 3 depicts the system after both development and habitat construction activities have occurred.

Step 2. General Background Data

A variety of data types will be necessary for the development of the information database. Much of this information will not be used directly in the analysis, but is essential to understand the specific nature of the system (Table 4). These data include descriptions of the system's physiography, geology, climate, water quality, and hydrodynamics. Particularly useful summaries can be found in the "Ecological Characterization" publications of the U.S. Fish and Wildlife Service (e.g., Fefer and Schettig 1980). These reports cover most of the major regions of the coastal United States and provide concise descriptions of the general environment and local habitats. Detailed information about a specific system can be obtained from several different sources. Upland and intertidal topography of the system can be determined from U.S. Geological Survey (USGS) topographic maps, while subtidal topography can be deduced from NOAA navigation charts. NOAA tide charts provide information on tidal patterns and ranges. Although there is presently no similar source of information on circulation patterns, these data may be available in the technical literature.

Climatology of the various regions of the United States has been described in publications of the U.S. Department of Commerce (e.g., Lautzenheiser 1972). More detailed meteorological information can be obtained from U.S. Weather Bureau publications and records. Useful data concerning weather and other local conditions may be maintained by Federal (e.g., U.S. Forest Service and U.S. Fish and Wildlife Service) or state agencies. Water flow records are kept for many waterways by the USGS, and water quality data are collected by a variety of Federal, state, and local agencies.

Records of past and present land-use patterns (agriculture, forestry, housing, etc.) are located in the publications of the U.S. Census Bureau and local planning agencies. Census Bureau reports provide historical data for the number of acres in agriculture and forestry and levels of production. Planning agencies and zoning boards may also maintain maps of land use. The U.S. Department of Transportation and equivalent state agencies often have aerial photographs taken over a number of years from which land-use patterns can be interpreted. Many of these agencies maintain databases and Geographical Information Systems for easy access and manipulation of the data.

Step 3. Identifying Habitats

The next step in the process is the identification of habitats present in a system. This step requires a common basis for classifying habitats. A variety of classification schemes have been devised, including Ray (1975), Cowardin et al. (1979), Simenstad et al. (1991), and Dethier (1990, 1992). Most are hierarchical in nature and place physical or chemical descriptors at the apex of the hierarchy. All classifications require a certain degree of oversimplification to be of practical use, and the differences between schemes can produce substantially different results. In following sections, the various classification schemes will be discussed and their strengths and weaknesses described. A "new" scheme is presented for implementation with the habitat evaluation framework.

Existing coastal habitat classification schemes

The habitat classification scheme of Ray (1975) places coastal type (coastal, coast-associated, and offshore) at the highest level of the classification (Table 5). Degree of exposure to waves (exposed or protected) is the second highest level of the hierarchy, and substrate type, vegetative cover, and salinity are at the bottom of the hierarchy. This scheme has two obvious shortcomings. First, it does not extend classification of the energy of the physical environment to estuarine environments. Second, differentiating between vegetative cover types or substrate types within separate salinity zones is difficult. For example, no distinction is made between oligohaline and polyhaline seagrass beds or hypersaline and mesohaline sands.

Cowardin et al. (1979) devised the most widely used wetland habitat classification scheme, which has system (marine, estuarine, and riverine) at the highest level of the hierarchy, subsystems (subtidal and intertidal) at the second level, and habitat class (substrate type, vegetative cover, and biologically produced structures such as reefs) at the third level (Table 6). The final tier in the scheme is that of modifiers. Modifiers appropriate in coastal habitats include tidal inundation (irregularly exposed, regularly flooded, and irregularly flooded), salinity zone (polyhaline, mesohaline, oligohaline, and fresh), and pH (acid, circumneutral, and alkaline). Special modifiers are also employed to describe human activities: diked, excavating, drained, farmed, and artificial.

Simenstad et al. (1991) modified the Cowardin system by restricting it to a subset of habitats found on the coast of Washington State. This scheme only covers nine habitat types: emergent marsh, mud flat, sandflat, gravel-cobble, eelgrass, nearshore subtidal, soft-bottom, near-shore subtidal hard-bottom, and water column.

Dethier (1990, 1992) modified the Cowardin scheme to resemble that of Ray (1975) by adding the physical energy (exposed to wave action, semi-exposed, and protected) at the habitat class level to better describe habitats found along the Washington coast (Table 7). A weakness of this scheme is that inconsistent terminology is applied among the system types. Marine intertidal habitats are classified by exposure to wave action (exposed, partly exposed, and protected), but marine subtidal habitats are classified as high, moderate, and low energy. Estuarine habitats, in turn, are termed as open, partly enclosed, and channel or slough. These distinctions are useful in describing the particular subset of environments encountered along the Washington coast, but a more uniform set of descriptors is needed for a national classification scheme.

Odum and Copeland (1974) devised a separate type of scheme that classifies ecosystems by their characteristic sources of energy. The major system categories are arctic, temperate, tropical, and man-made; the major energy sources are light, wave or current action, and type of organic material. System types (habitat classes) include most of those previously listed by other authors but in much less detail. An advantage of the Odum and Copeland scheme is that it is part of a theoretical model for predicting changes in diversity because of stress. The major disadvantage is that it ignores the two main factors that describe coastal habitats, salinity regime and substrate type.

Coastal habitat classification scheme

The Coastal Habitat Classification Scheme (CHCS) used in this report is an adaptation of Cowardin et al. (1979) and incorporates many of the modifications of Simenstad et al. (1991) and Dethier (1990, 1992). The first modification is the elimination of all noncoastal or terrestrial-wetland habitat types (e.g., Scrub-Scrub Wetland and Forested Wetland) from the Cowardin scheme (Table 8). Evaluation of these particular habitats is more appropriately performed with other methods such as WET (Adamus and Stockwell 1983; Adamus et al. 1987). Continental slope and abyssal environments were also excluded for the sake of practicality.

A second modification is the priority assigned to descriptors at the apex of the hierarchy. The top level of CHCS is an amplification of the system level of Cowardin et al. (1979). The marine system descriptor is retained, but the estuarine descriptor is replaced by polyhaline, mesohaline, and oligohaline; and the riverine descriptor is limited to tidal riverine. The elevation of salinity modifiers to the system level better reflects the importance of this factor in controlling the distribution of coastal organisms.

The next level of CHCS is the same as the subsystems of Cowardin et al. (1979), that is, subtidal and intertidal. Finally, individual habitats are described by substrate type and vegetative cover (Table 8). Five categories of modifiers are incorporated into the scheme: zones of physical energy, tidal inundation, artificial habitats, special salinity modifiers, and special substrate modifiers. The zones of physical energy are identified as suggested by Dethier (1990) for subtidal habitats (high, moderate, and low). Tidal inundation is classed as regularly or irregularly flooded. Artificial habitats (jetties, diked areas, agricultural lands, etc.) are included as a modifier of habitat type rather than a separate class of habitat, because they do not occur naturally. Hypersaline and euhaline are added as special salinity modifiers, while special substrate modifiers include organic and mixed sediments.

Data necessary for identifying habitats

Once a classification scheme has been selected, identification of the habitats can begin. From the discussion of the various classification schemes and the priorities assigned in the CHCS, the two most important types of data to assemble obviously are salinity and sediment distributions. Not only are most estuarine and coastal habitats controlled by these factors, but in many cases they are defined by them (e.g., marine rock bottom and oligohaline mud bottom). A map of salinity zones and sediment types will, in itself, provide the data necessary to map a large part of the habitats in the system. Many of the habitats in the example system (Figure 2) were "mapped" based on the distribution of salinity and sediments. Salinity distributions can be obtained to some extent from National Estuarine Inventory Maps (NOAA 1985); however, these data are not comprehensive. The output from a hydraulic model or reports of direct measurements taken over long time periods would be preferable. A concise review of hydraulic modeling in estuarine and coastal regions has been prepared by Hall, Dortch, and Bird (1988). Models are maintained by many Federal, state, and local agencies. Sediment distributions can be determined from NOAA charts, publications of the U.S. Soil Survey, state Geological Surveys or other state agencies, and U.S. Army Corps of Engineers' studies. Sediment data may also be found in reports on the geology or benthic ecology of a system.

Step 4. Habitat Attributes

Step 4 is the description of habitat structures and functional attributes associated with each habitat. This kind of information can be found in the Ecological Characterization, Biological Report, and Community Profile Series of the U.S. Fish and Wildlife Service, Species Profiles Series of the U.S. Fish and Wildlife Service and U.S. Army Corps of Engineers, and the general scientific literature (Table 9). Additional information can be found in publications of NOAA's Estuarine Living Marine Resources Program. Documents from this program summarize the distribution, seasonal occurrence, and abundance of many fish and invertebrate species (e.g., Nelson et al. 1991). Data on other aspects of the biology and ecology of a system may be present in the general technical literature or deduced from regional species lists. Biological and economic information can be obtained from records of fisheries' landings and hunting and wildlife records (e.g., NOAA 1991). Archeological records may help provide insight to historical species occurrences and land-use patterns. Nontraditional methods such as personal interviews, questionnaires, tax records, demographic studies, and oral histories may also provide insight to the extent of resources or significant events affecting resource availability and utilization.

The association of characteristic habitat structures and functional attributes begins by listing the major elements of biological communities (Table 1). Two components that have been excluded from the list are microflora (bacteria and protozoa) and plankton. Microflora have been left out because of the limited amount of information available on their quantitative contributions to the ecology of many habitats. Plankton have been removed because the association of these organisms with many habitats is a matter of passive transport and not active habitat selection.

The five functional attributes chosen for this method are derived in part from Simenstad et al. (1991) (Table 10) and in part from general ecological considerations. The attributes are used to characterize the role of each biotic component and its association with a particular habitat. Three attributes are borrowed from Simenstad et al. (1991): structure, feeding, and reproduction. The structural attribute represents the use of some portion of the habitat for substrate, attachment, refuge, or other uses of physical structure essential to survival. Feeding simply represents the use of a habitat for providing all or part of a population's nutritional requirements. Reproduction represents the use of the habitat for either reproduction or development. Two additional attributes, primary and secondary production, are included to express the nature of the productivity individual components supply to the ecosystem.

It should be noted at this point that the attributes presented above are being used for the purpose of illustration and do not represent the only attributes that can be employed. For example, sediment stabilization, nutrient removal and transformation, and sediment and toxicant retention are commonly utilized in wetland assessment. Sediment stabilization and erosion control are often included among functions of seagrass beds. These and other attributes should be incorporated into the framework wherever they are viewed as important to the habitats or ecosystems involved.

A matrix of all coastal habitats and their attributes is presented in Table 11. It was constructed by listing the CHCS (Table 8), the major biotic components for each habitat type (Table 1), and assigning the appropriate functional attributes (Table 10). The total matrix does not have to be constructed for each system; a smaller matrix including only the relevant habitats will be needed. A matrix for the "Anywhere Bay" system is presented in Table 12. At first glance, even this matrix appears to be a "laundry list" of ecological variables. Since it is doubtful that even a modestly sized system matrix could be filled in completely, the matrix is intended to serve as focus for determining what is already known about a system and for deciding what information is critical to evaluating the system. The critical attributes are then selected and listed as a separate matrix. This critical attribute matrix is the basis for all subsequent discussions and calculations. The choice of critical attributes is obviously the most important step of the framework. Just as the selection of target species in a species-based method (e.g., HEP) injects an inherent bias to the analysis, the choice of critical attributes drives the interpretation of results from the framework. The choice of attributes must be made purely on the basis of what is believed to be important to maintenance of the habitat and its contribution to the functioning of the system. These choices must be made even if a "laundry list" is the ultimate result. Developing such lists may not seem practical, yet, neither is a "minimal list" approach if it ignores important data or ecological relationships. The extent of the critical attribute matrix, however, need not be overwhelming. The example critical attribute matrix (Table 13) details the structure and function of 10 different habitat types. Less than a third of the original system habitat-attributes needed to be considered, and all of the attributes listed are commonly found in extant databases.

Step 5. Regional Attribute Values

After the selection of critical attributes, the next step is to assemble information on expected attribute values. Expected values are those data representative of the same attribute, habitat type, and geographical region. For present purposes, geographical regions are classified by biogeographic provinces (Ekman 1953). These provinces are defined primarily on zoological distributions, current patterns, and hydrological conditions and reflect broad-scale patterns of species and community distributions (Table 14). Ekman (1953) is the basis for virtually all subsequent schemes (e.g., Bailey 1976, 1978) and will be used here. Phytogeographical distributions have also been described, but generally correspond to the same distribution patterns as the zoogeographical provinces (Round 1981).

Information on attribute values can be found in many of the same documents that provided data on habitat structure and functions, i.e., Ecological Characterization, Biological Report and Community Profile Series of the U.S. Fish and Wildlife Service, Species Profiles Series of the U.S. Fish and Wildlife Service and U.S. Army Corps of Engineers, and NOAA's Estuarine Living Marine Resources Program. Additional information can be found in the technical literature and governmental reports.

Regionally adjusted attribute values for the example system are presented in Table 15. Note that polyhaline mud flats are broken down into two parts: A and B. In this case, Mud Flat B only supports 50 percent of the infauna normally associated with that type of habitat. This condition in turn results in reduced feeding opportunities for shrimps, crabs, fish, and birds. The ability to divide individual habitat categories into separate patches illustrates the flexibility of the framework. The patches can be analyzed individually and the results easily incorporated into the framework. The degree of detail that a particular analysis utilizes is left up to the end user.

Step 6. Habitat Mapping

Mapping of habitats and measurement of habitat areas (Step 6) follows assembly of the attribute information. The most cost-effective approach to habitat mapping is to use pre-existing maps or data. Many agencies maintain maps of economically important habitats such as oyster beds or seagrass beds (e.g., NOAA 1989). As previously mentioned, coastal wetlands are currently being mapped by NOAA. Some state agencies have also produced habitat maps of their coastlines. For instance, the Maine Geological Survey has mapped all intertidal habitats (Timson 1977), and Texas has produced habitat maps for both intertidal and subtidal habitats (e.g., Brown et al. 1976; White et al. 1983). As previously discussed, the distribution of many habitats can be deduced from sediment and salinity. This is particularly true of unvegetated sediment habitats that are defined by these factors (e.g., polyhaline sand). It was assumed for the example system habitat map (Figure 2) that all unvegetated substrate habitats could be mapped in this fashion. Marsh, rocky intertidal, and seagrass habitats were assumed to have been mapped by aerial photography and site visits.

While locating pre-existing maps is obviously a preferred course of action, it is essential that they not be used in an indiscriminate manner. Before any map is used, the underlying information must be closely scrutinized to determine its age, method of collection, and quality. A map will only be as good as the data on which it is based. Another common source of error in pre-existing maps is scale. Maps of subtidal resources are generally produced by assuming the conditions at a sample site are representative of a particular physical area or cell. A precise formula or even a general means does not exist to determine the relationship between sample size and number, cell size and number, and the size of the system. Obviously, the more samples that are taken in a cell and the more cells that are sampled, the more likely it is that the data will be representative.

When insufficient data are available to formulate an accurate habitat map, obtaining the information in a cost-effective manner is still possible. Aerial photography provides a rapid, accurate, and repeatable mechanism for mapping marshes and intertidal zones. Ground-truthing is required to ensure the accuracy of the method, but can be done quickly and at low cost. Land-based photography can also be employed. Subtidal resources can be mapped with a remotely operated vehicle (ROV) or sediment-profiling camera. ROVs have been used to survey both species-specific habitats such as scallop beds (Langton and Robinson 1990; Thouzeau, Robert, and Ugarte 1991) and general faunal assemblages. Sediment-profiling cameras have been used to rapidly map sediment distributions over large areas (Rhoads and Germano 1982). Diver-operated cameras may be effective in many situations. Maps can also be constructed from the results of traditionally based sampling efforts such as benthic surveys (e.g., Brown et al. 1976; White et al. 1983).

Once pre-existing habitat maps and other information have been obtained, the question of the best way to store, analyze, and present the data still remains. The simplest method is to plot all of the habitats on a single map (e.g., Figure 2) and then use a planimeter to measure the area of each habitat type. Data from these measurements can be stored and analyzed on any computer spreadsheet program. A more expensive but more accurate method would be to use an image-analysis system. An image-analysis system may consist of a standard personal computer outfitted with an image capture card, image-analysis software, and a video camera. Maps are scanned into the system and the imaging software used to edit and measure the captured images. Most software packages also provide statistical analysis. Data can be stored on standard floppy disks or mass storage devices (e.g., Bernoulli disks, replaceable hard drives, and optical storage) if a large volume of data is involved. Perhaps the most powerful method available is the Geographical Information System (GIS). Davis and Schultz (1990) provided an overview of GIS structure, operations, and practical considerations associated with its use. A more detailed account can be found in Burrough (1986). As a rule, a GIS will be too expensive to set up solely to perform the analysis outlined in this report. If, however, one is available and part of the required data has already been entered, then the GIS may be the preferred option for data storage, analysis, and presentation.

Step 7. Attribute Measures

Step 7 is to provide a quantitative measure for each of the critical attributes. Data sources specific to the system under study have obvious priority in the process. However, there will probably be little or no information available on many habitat types within a specific system or for many of the attributes. In this situation, representative data from other systems in the same region may be substituted as long as the environmental conditions are representative. That is, data for a seagrass bed exposed to moderate wave action should be derived from seagrass beds in nearby systems in similar conditions. In some cases, compar:ᵇ'e data may not exist, and attributes must be measured directly. Simenstad e. ... (1991) provided comprehensive recommendations for measuring attributes of a wide variety of coastal habitats. Additional recommendations can be found in Price, Irvine, and Franham (1980), Nielsen and Johnson (1983), Baker and Wolff (1987), and Fredette et al. (1990).

productivity by benthic invertebrate fauna were not significant, and amounts of seagrass attributes in the system were increased (Table 17). Obviously, the oligohaline marsh was a limited resource to this system, and much of its contribution was lost. Planted seagrasses initially provide only a portion of what is expected from natural habitats, but over time reach normal levels (Tables 17 and 18). Further repercussions can also be estimated for other habitats and for different time periods. In the example system, physical alterations associated with construction are predicted to result in changes in water flow and water retention. Fresh water flows further into the estuary than previously, and a major portion of mesohaline subtidal muds become oligohaline muds (Table 17). Over time, the oligohaline muds are predicted to become eutrophic with surplus production of infauna (Table 18). Whether these losses and gains represent an important long-term alteration of the system can probably be determined only with experience.

At the present time, predictive models or conceptual rules do not exist for determining what a specific change in an attribute or loss in the total amount of a habitat may mean to a system. The actual effect of trading habitats or their attributes will vary with the environmental status of each system. For instance, planting a seagrass bed in a highly polluted system may have a high probability of failure because of water quality. Planting of marsh habitat would be more likely to succeed because of the greater resilience of these habitats and could help improve water quality by sequestering pollutants. Planting either habitat in an identical but pristine system would probably have little discernible effect.

Another use of the framework would be to assess the current environmental status of a system by comparing the current situation with estimated historical conditions. In this case, measures of historical habitat areas or functional attributes will probably not be available, so estimates must be made. Habitat areas can be estimated from existing distributions and historical records. Historical attribute values can be assumed to be 100 percent of expected levels. This is a conservative approach since it presumes that a habitat will maintain normal levels of function in the absence of human-induced disturbance. A similar assumption can also be made for modern habitats if there is sufficient reason to assume they are not affected by human-induced disturbance. Results can then be compared to determine the nature and extent of habitat changes in the system. This comparison could then act as the baseline for determining what attributes are the most important to restore or enhance.

3 Discussion

This report describes a conceptual framework for a new method to assess environmental impacts from trade-offs of coastal habitats. It represents an inherently different approach to methods in current use in that it provides a mechanism to examine system-wide repercussions of changes in the areal extent of habitats and their associated habitat attributes (ecological functions). It is essentially an inventory and accounting procedure based on the biological structure and functions of habitats. Each habitat attribute is considered separately and its quantitative contribution is expressed as a percentage of expected values for that region. Output consists of a listing of the habitat types in the system, their proportions, and a measure of their total contribution to the system (attribute values multiplied by habitat area). Although models are not available to predict what the precise effect of a particular alteration of a system might mean, this framework can be considered the first step towards a more inclusive conceptual model. By listing changes in each attribute separately, the method permits a more detailed analysis than is generally performed and prevents underestimation of the importance of any one attribute.

The method outlined in this report is also different from existing procedures in that it requires a substantial amount of initial effort. While some of this effort will be expended in assembling and compiling the information necessary for subsequent calculations, the bulk will be expended in consensus-building and decision-making activities. Unlike the conventional project-specific approach, the new method is oriented towards establishing long-term environmental goals for the management of a system. The most important step in the process of constructing the framework, the determination of the critical attributes, requires that a consensus be reached concerning which attributes are most important to the long-term health of the system. Likewise, the final results can only be applied if there is some common ground among managers regarding the direction in which the system should be managed. These decisions are presently made or negotiated every time there is a new project. Implementation of the new framework can act as a stimulus to formulating a single long-term strategy for managing habitat trade-off issues. The expenditure of time and effort at the outset should be repaid by the elimination of unnecessary and repetitive efforts associated with later projects. Even if common ground cannot be established among decision-makers, the new framework can provide a uniform approach for subsequent analysis and discussion of the issues associated with trading habitats.

At the present time, case studies testing the framework are just getting underway. Examination of the framework's underlying assumptions and evaluation of its practical limitations are required before the framework can be applied as a practical field method. The results of the case studies will be published as completed and further modifications and refinements of the framework made as experience dictates.

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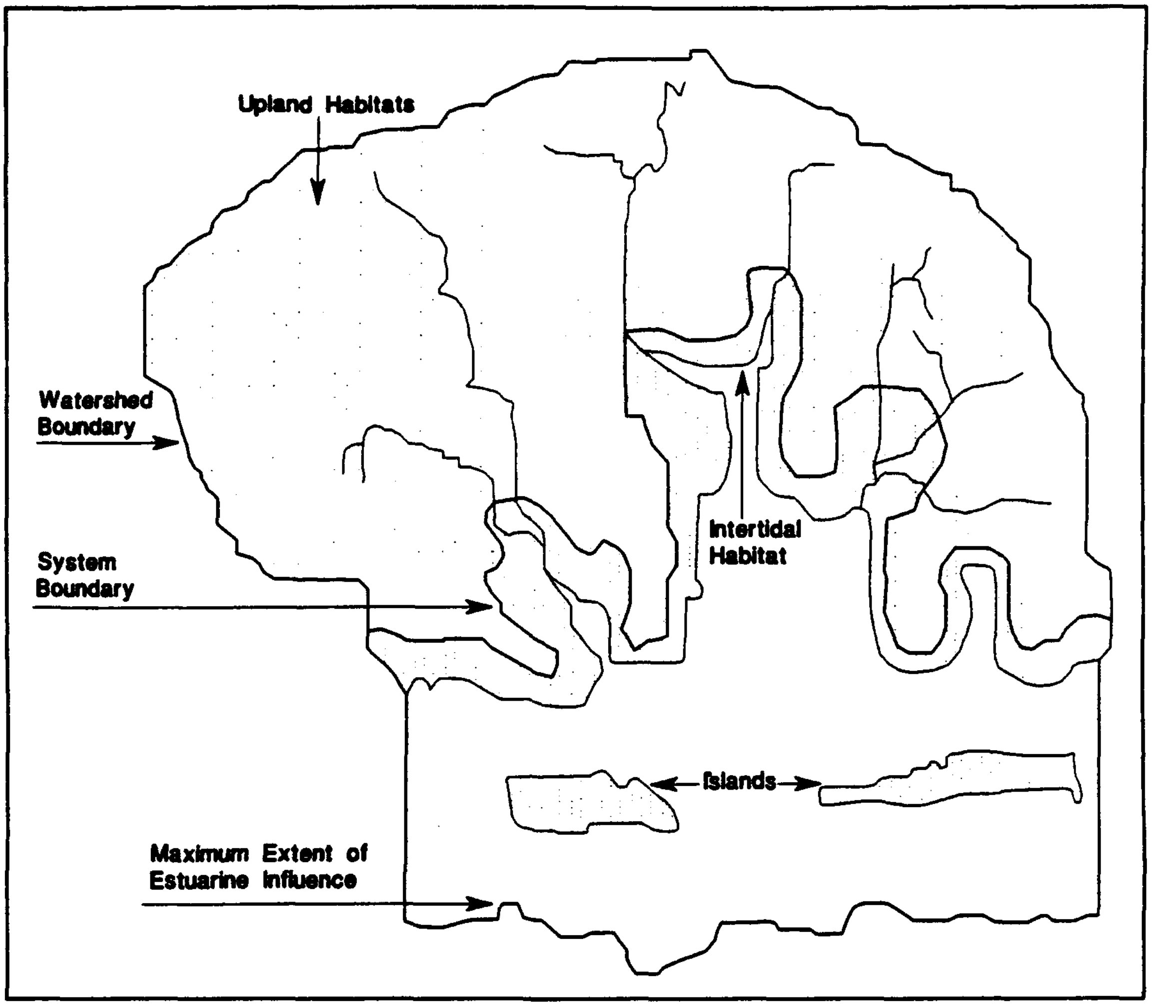

Figure 1. Boundaries of Anywhere Bay System

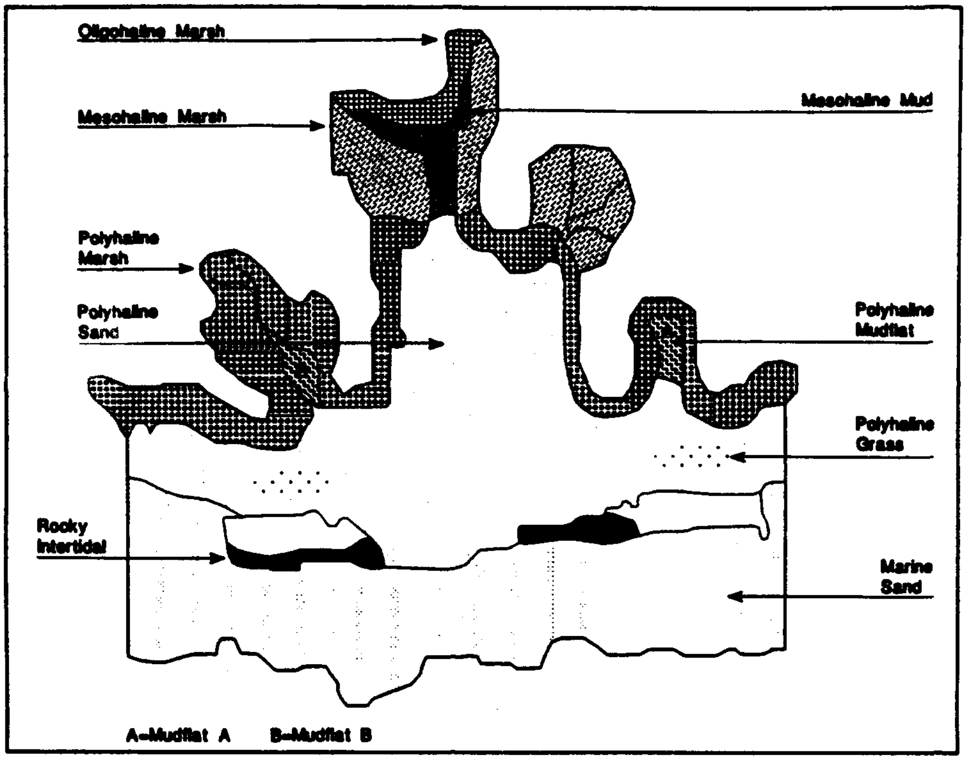

Figure 2. Habitat map of system before project

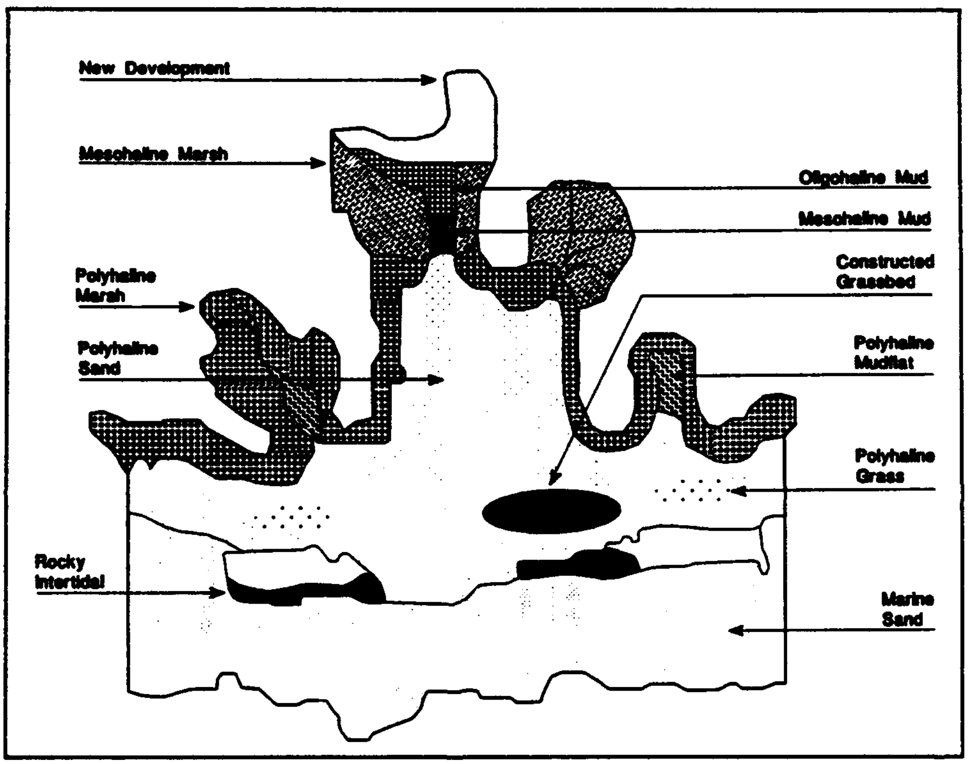

Figure 3. Habitat map of system after project

Table 1
Structural Elements of Biological Communities

Elements	Examples
Microflora	Bacteria, Fungi
Algae	
Microalgae	Diatoms
Macroalgae	*Ulva*, Kelp
Vascular Plants	Seagrasses, Marsh Grasses
Meiofauna	
Meioinfauna	Nematodes
Meioepifauna	Copepods
Macrofauna	
Macroinfauna	Polychaetes, Clams
Mobile Macro-Epifauna	Amphipods, Isopods
Attached Macro-Epifauna	Barnacles
Megainvertebrates	Lobsters, Crabs, Shrimp
Demersal Fishes	Flounder
Nektonic Fishes	Anchovies
Shorebirds	Willets, Terns
Non-Shorebirds	
Marine Reptiles	Sea Turtles
Non-Marine Reptiles	Rattlesnakes
Marine Mammals	Seals, Otters
Non-Marine Mammals	Raccoons

Table 2
Evaluating Coastal Habitats—Steps in the Process

1. Identify system boundaries.
2. Collect and compile background information.
3. Identify habitats.
4. Identify critical structural and functional attributes.
5. Summarize expected range of habitat attribute values.
6. Map local habitats.
7. Estimate or measure the functional attributes of habitats.
8. Express functional attributes (Step 7) as a percentage of regional average (Step 5).
9. Multiply habitat area by regionally adjusted attribute values (Step 8).
10. Compare values for habitat diversity (number of habitats) and total attributes (Step 9) for the entire system over time or between different management scenarios.

Table 3
Habitat Types and Total Areas (hectares) for Anywhere Bay

Habitat Type	Before Project	After Project
Marine Sand	2,000	2,000
Marine Rocky Intertidal	60	60
Polyhaline Marsh	800	800
Polyhaline Grass	250	250
Polyhaline Constructed Grass	-	100
Polyhaline Sand	2,500	2,400
Polyhaline Intertidal Mud Flat	100	100
Mud Flat A	50	50
Mud Flat B	50	50
Mesohaline Subtidal Mud	100	30
Mesohaline Marsh	400	350
Oligohaline Marsh	800	0
Oligohaline Subtidal Mud	0	50
Lost to Development		860
Total	7,110	6,250

Table 4
Background Data Sources

Data Type	Data Source
System Boundaries	NOAA Estuarine Inventory Atlas USGS Hydrological Unit Maps USGS Topographic Maps
Topography	USGS Topographic Maps NOAA Navigation Charts
Geology	U.S. Geological Survey State Geological Survey
Metereology	U.S. National Weather Service
Hydrology	U.S. Geological Survey Hydraulic Models
Sediments	U.S. Army Corps Engineers Soil Survey
Chemistry/Water Quality	U.S. Environmental Protection Agency, State Water Resources Water Quality Models

Table 5
Habitat Classification Scheme of Ray (1975)

Coastal Environments

- Exposed
  - Rocky substrate
    - Calcareous
    - Weakly calcareous or noncalcareous
  - Unconsolidated substrate
    - Low organic content
      - Gravel
      - Sand
      - Silt
      - Clay
  - High organic content
- Protected
  - Rocky substrate
    - Calcareous
    - Weakly calcareous or noncalcareous
  - Unconsolidated substrate
    - Low organic content
      - Gravel
      - Sand
      - Silt
      - Clay
    - High organic content
- Deltas

Coast-Associated Environments

- Submarine vegetation beds
  - Algae
  - Vascular plants
- Estuaries
  - Mixoeuhaline
  - Polyhaline
  - Mesohaline
  - Oligohaline
- Lagoons
  - Hypersaline
  - Euhaline
  - Mixoeuhaline
  - Polyhaline
  - Mesohaline
  - Oligohaline
- Tidal salt marshes
- Nontidal salt marshes and flats
- Mangrove
- Drainage basins
  - Extent
  - Type

Offshore Environments

- Kelp beds
- Coral reefs near continents
  - Algal
  - Coral
- Coral reefs near islands
  - Algal
  - Coral
- Drowned reefs
  - Insular environments
  - Continental shelves
  - Submarine canyons
  - Ice
  - Continental slope
  - Offslope environments

Man-made Environments

- Spoil
- Reefs
- Maricultural

Special Interest

- Bird rookeries
- Sea turtle rookeries
- Sea mammal rookeries
- Seasonal fish concentrations

Water Circulation Bodies

- Inshore circulation cells
- Larger scale circulation cells
- Upwelling systems

Table 6
The Habitat Classification Scheme of Cowardin et al. (1979)[1]

System	Subsystem	Class
Marine	Subtidal	Rock bottom Unconsolidated bottom Aquatic bed Reef
	Intertidal	Rocky shore Unconsolidated bottom Aquatic bed Reef
Estuarine[2]	Subtidal	Rock bottom Unconsolidated bottom Aquatic bed Reef
	Intertidal	Rocky shore Unconsolidated bottom Aquatic bed Reef Streambed Emergent wetland Scrub-scrub wetland Forested wetland
Riverine	Tidal	Rock bottom Unconsolidated bottom Rocky shore Aquatic bed Emergent wetland

[1] Coastal habitats only.
[2] Salinity modifiers include Hypersaline, Euhaline, Polyhaline, Mesohaline, Oligohaline.

Table 7
Habitat Classification Scheme of Dethier (1990)

Marine	Estuarine
Intertidal Rock (solid bedrock) Exposed Partially exposed Semiprotected and protected Boulders Exposed Partially exposed Semiprotected and protected Hardpan Cobble Partially exposed Mixed coarse Semiprotected and protected Gravel Partially exposed Semiprotected Sand Exposed and partially exposed Semiprotected Mixed fine Semiprotected and protected Mud Protected Organic (wood chips, marine detritus) Artificial Reef Subtidal Bedrock and boulders Moderate to high energy Cobble High energy Gravel High energy Mixed fine High energy Moderate energy Low energy Mud and mixed fine Low energy Organic Artificial Reef	Intertidal Bedrock Open Hardpan Mixed coarse Open Partly enclosed Sand Open Partly enclosed Mixed fine Partly enclosed Lagoon Mixed fine and mud Partly enclosed Lagoon Channel-Slough Mud Partly enclosed and closed Organic Partly enclosed Backshore Artificial Reef Subtidal Bedrock and boulders Open Cobble Open Mixed coarse Open Sand Open Partly enclosed Mixed fine Open Sand and mud channel Organic Artificial Reef

Table 8
Coastal Habitat Classification Scheme

Marine (Euhaline)

- Subtidal
  - Rock bottom
    - Bedrock
    - Rubble
  - Unconsolidated bottom
    - Cobble-gravel
    - Sand
    - Mud
  - Aquatic bed
    - Rooted vascular
    - Algal
  - Reef
    - Coral algal
    - Worm
    - Mollusc
- Intertidal
  - Rock bottom
    - Bedrock
    - Rubble
  - Unconsolidated bottom
    - Cobble-gravel
    - Sand
    - Mud
  - Aquatic bed
    - Rooted vascular
    - Algal
  - Marsh

Polyhaline

- Subtidal
  - Rock bottom
    - Bedrock
    - Rubble
  - Unconsolidated bottom
    - Cobble-gravel
    - Sand
    - Mud
  - Aquatic bed
    - Rooted vascular
    - Algal
  - Reef
    - Worm
    - Mollusc
- Intertidal
  - Rock bottom
    - Bedrock
    - Rubble
  - Unconsolidated bottom
    - Cobble-gravel
    - Sand
    - Mud
  - Aquatic bed
    - Rooted vascular
    - Algal
  - Marsh

Mesohaline

- Subtidal
  - Rock bottom
    - Bedrock
    - Rubble
  - Unconsolidated bottom
    - Cobble-gravel
    - Sand
    - Mud
  - Aquatic bed
    - Rooted vascular
    - Algal
  - Reef
    - Worm
    - Mollusc

Oligohaline

- Subtidal
  - Rock bottom
    - Bedrock
    - Rubble
  - Unconsolidated bottom
    - Cobble-gravel
    - Sand
    - Mud
  - Aquatic bed
    - Rooted vascular
    - Algal
  - Reef
    - Mollusc

(Continued)

Table 8 (Concluded)

Intertidal Rock bottom Bedrock Rubble Unconsolidated bottom Cobble-gravel Sand Mud Aquatic bed Rooted vascular Algal Marsh	Intertidal Rock bottom Bedrock Rubble Unconsolidated bottom Cobble-gravel Sand Mud Aquatic bed Rooted vascular Algal Marsh
Tidal Riverine	
Subtidal Rock bottom Bedrock Rubble Unconsolidated bottom Cobble-gravel Sand Mud Aquatic bed Rooted vascular Intertidal Rock bottom Bedrock Rubble Unconsolidated bottom Cobble-gravel Sand Mud Aquatic bed Rooted vascular Marsh	

Note: Modifiers are as follows:
Energy Environment: High, Moderate, and Low.
Tidal Inundation: Regularly flooded and Irregularly flooded.
Artificial: Jetty, Diked, Agriculture, and Aquaculture or Mariculture.
Special Salinity: Hypersaline.
Special Substrate: Organic and Sediment Mixtures.

Table 9
Coastal Habitat Profiles

Oyster Reefs
Bahr, L. N., and Lanier, W. P. (1981) - Georgia Intertidal Reefs Burrell, V. G. (1986) - American Oyster--South Atlantic. Couch, D., and Hassler, T. J. (1989) - Olympia Oyster. Pauley, G. B., Van Der Ray, B., and Troutt, D. (1988) - Pacific Oyster. Seller, M. A., and Stanley, J. G. (1984) - American Oyster--North Atlantic. Stanley, J. G., and Seller, M. A. (1986a) - American Oyster--Gulf of Mexico. Stanley, J. G., and Seller, M. A. (1986b) - American Oyster--Mid-Atlantic.
Other Mollusc Habitats
Bay Scallop Fay, C. W., Neeves, R. J., and Pardue, G. B. (1983). Sea Scallop Mullen, D. M., and Moring, J. R. (1986). Blue Mussel Newell, R. I. E. (1989). California Sea Mussel and Bay Mussel Shaw, W. N., Hassler, T. J., and Moran, D. P. (1988).
Intertidal Flats (Need Pacific Coast)
Peterson, C. H., and Peterson, N. M. (1979) - North Carolina. Whitlach, R. B. (1982) - New England.
Sandy Beaches
McLachlan, A., and Erasmus, T. (1983).
Dunes
Wiedemann, A. M. (1984).
Corals
Jaap, W. C. (1984) - South Florida. Porter, J. W. (1987) - South Florida.
Worm Reefs
Zale, A., and Merrifield, S. G. (1989).
Mangroves
Odum, W. E., McIvor, C. C., and Smith, T. J. (1982) - South Florida.
Marshes
Stout, J. P. (1984) - Gulf of Mexico. Teal, J. M. (1986) - New England. Wiegart, R. G., and Freeman, B. J. (1990) - Southeastern Atlantic. Zedler, J. B. (1984) - California.
(Continued)

Table 9 (Concluded)

Seagrasses
Kantrud, A. H. (1991) *Ruppia*. Phillips, R. C. (1984) - Pacific Northwest. Thayer, G. W., and Fonseca, M. S. (1984) - Atlantic Coast. Zieman, J. C. (1985) - South Florida.
Kelp
Foster, M. S., and Schiel, D. R. (1985) - West Coast.
Unvegetated Unconsolidated (Soft-Bottom) Subtidal
Armstrong, N. E. (1987) - Texas.
Rocky Intertidal
Consolidated (Hard Bottom) Subtidal

Table 10
Functional Attribute Hierarchy of Simenstad et al. (1991)

Reproduction

- General
  - Light
  - Salinity
  - Sound
  - Temperature
  - Turbidity
  - Water/sediment quality
- Elevation
  - Intertidal
  - Subtidal
  - Riparian
- Substrate
  - Sediment
  - Emergent vascular plants
  - Macroalgae
  - Riparian vegetation

Refuge and Physiology

- General
  - Salinity
  - Sound
  - Temperature
  - Turbidity
  - Water/sediment quality
- Physical complexity
  - Bathymetric features
  - Horizontal edges
  - Vertical relief
  - Water movement
- Biological complexity
  - Macron
  - Emergent vascular plants
  - Submergent vascular plants

Feeding

- General
  - Carrion
  - Detritus
  - Graveling
  - Light
  - Salinity
  - Sound
  - Temperature
  - Turbidity
  - Water/sediment quality
- Plants
  - Microalgae
  - Macroalgae
  - Emergent vascular plants
  - Submergent vascular plants
- Invertebrates
  - Benthic
  - Epibenthic
  - Neustonic
  - Pelagic
- Vertebrates
  - Demersal
  - Water column
  - Neustonic
  - Terrestrial

Table 11
Coastal Habitat Structure and Functional Attributes Matrix

	Algae micro	Algae macro	Vascular plants	Meio- infauna	Meio- epifauna	Macro- infauna	Macro-Epifaunal mobile	Macro-Epifaunal attached
Marine								
Subtidal								
Rock Bottom								
Bedrock	p^1	p^1			p^2, S		p^2, F	p^2, S
Rubble	p^1	p^1			p^2, S		p^2, F	p^2, S
Unconsolidated Bottom								
Cobble-Gravel	p^1	p^1		p^2, F			p^2, F	p^2, S
Sand	p^1	p^1		p^2, F	p^2, F	p^2, F	p^2, F	
Mud	p^1	p^1		p^2, F	p^2, F	p^2, F	p^2, F	
Aquatic Bed								
Rooted Vascular	p^1, S	p^1, S	p^1	p^2, F	p^2, S, F	p^2, F	p^2, S, F	p^2, S
Algal	p^1, S	p^1		p^2, F	p^2, S, F	p^2, F	p^2, S, F	p^2, S
Reef								
Coral/Algal	p^1, S				p^2, S, F		p^2, S, F	p^2, S
Worm	S				p^2, S, F		p^2, S, F	p^2, S
Mollusc	p^1, S			p^2, F	p^2, S, F	p^2, F	p^2, S, F	p^2, S
Intertidal								
Rock Bottom								
Bedrock	p^1	p^1			p^2, S		p^2, S, F	p^2, S
Rubble	p^1	p^1			p^2, S		p^2, S, F	p^2, S
Unconsolidated Bottom								
Cobble-Gravel	p^1	p^1		p^2, F	p^2, F	p^2, F	p^2, F	p^2, F
Sand	p^1	p^1		p^2, F	p^2, F	p^2, F	p^2, F	
Mud	p^1	p^1		p^2, F	p^2, F	p^2, F	p^2, F	
Aquatic Bed								
Rooted Vascular	p^1, S	p^1, S	p^1	p^2, F	p^2, S, F	p^2, F	p^2, S, F	p^2, S
Algal	p^1, S	p^1		p^2, F	p^2, S, F	p^2, F	p^2, S, F	p^2, S
Marsh	p^1, S	p^1, S	p^1	p^2, F	p^2, S, F	p^2, F	p^2, S, F	p^2, S

Note: Functional Attributes associated with a habitat are as follows: P^1 = Primary Productivity. P^2 = Secondary Productivity. S = Structure (Substrate, Refuge, etc.). F = Feeding. R = Reproduction (and Development).

Table 11 (Continued)

	Mega-invertS	Demersal fishes	Nektonic fishes
Marine			
Subtidal			
Rock Bottom			
Bedrock	P^2, F	F	F
Rubble	P^2, F	F, S	F
Unconsolidated Bottom			
Cobble-Gravel	P^2, F	F	F
Sand	P^2, F	F, S	F
Mud	P^2, F	F, S	F
Aquatic Bed			
Rooted Vascular	P^2, F	S, F, R	S, F, R
Algal	P^2, F	S, F, R	S, F, R
Reef			
Coral/Algal	P^2, S, F	S, F, R	S, F, R
Worm	P^2, S, F	F	F
Mollusc	P^2, S, F	S, F, R	S, F, R
Intertidal			
Rock Bottom			
Bedrock	F	F	F
Rubble	F, S	F, S	F
Unconsolidated Bottom			
Cobble-Gravel	F, S	F, S	F
Sand	F	F	F
Mud	F	F	F
Aquatic Bed			
Rooted Vascular	P^2, S, F, R	S, F, R	S, F, R
Algal	P^2, S, F, R	S, F, R	S, F, R
Marsh	P^2, S, F, R	S, F, R	S, F, R

Table 11 (Continued)

	Shore Birds	NonShore Birds	Marine Reptiles	NonMarine Reptiles	Marine Mammals	NonMarine Mammals
Marine						
Subtidal						
Rock Bottom						
Bedrock						
Rubble						
Unconsolidated Bottom						
Cobble-Gravel			F			
Sand			F		F	
Mud					F	
Aquatic Bed						
Rooted Vascular			F		F	
Algal			F		F	
Reef						
Coral/Algal			F			
Worm			F			
Mollusc			F		F	
Intertidal						
Rock Bottom						
Bedrock	F	F	F			F
Rubble	F	F	F			F
Unconsolidated Bottom						
Cobble-Gravel	F	F	F			F
Sand	F	F	R			F
Mud	F	F				F
Aquatic Bed						
Rooted Vascular	F		F			
Algal	F	F				F, R
Marsh	F, R	F, R		F		F, R

Table 11 (Continued)

	Algae micro	Algae macro	Vascular plants	Meio- infauna	Meio- epifauna	Macro- infauna	Macro-Epifauna mobile	Macro-Epifauna attached
Polyhaline								
Subtidal								
Rock Bottom								
Bedrock	p^1	p^1			p^2, S		p^2, F	p^2, S
Rubble	p^1	p^1			p^2, S		p^2, F	p^2, S
Unconsolidated Bottom								
Cobble-Gravel	p^1	p^1		p^2, F			p^2, F	p^2, S
Sand	p^1	p^1		p^2, F	p^2, F	p^2, F	p^2, F	
Mud	p^1	p^1		p^2, F	p^2, F	p^2, F	p^2, F	
Aquatic Bed								
Rooted Vascular	p^1, S	p^1, S	p^1	p^2, F	p^2, S, F	p^2, F	p^2, S, F	p^2, S
Algal	p^1, S	p^1		p^2, F	p^2, S, F	p^2, F	p^2, S, F	p^2, S
Reef								
Worm					p^2, S, F		p^2, S, F	p^2, S
Mollusc	p^1, S			p^2, F	p^2, S, F	p^2, F	p^2, S, F	p^2, S
Intertidal								
Rock Bottom								
Bedrock	p^1	p^1			p^2, S		p^2, S, F	p^2, S
Rubble	p^1	p^1			p^2, S		p^2, S, F	p^2, S
Unconsolidated Bottom								
Cobble-Gravel	p^1	p^1		p^2, F	p^2, F	p^2, F	p^2, F	p^2, F
Sand	p^1	p^1		p^2, F	p^2, F	p^2, F	p^2, F	
Mud	p^1	p^1		p^2, F	p^2, F	p^2, F	p^2, F	
Aquatic Bed								
Rooted Vascular	p^1, S	p^1, S	p^1	p^2, F	p^2, S, F	p^2, F	p^2, S, F	p^2, S
Algal	p^1, S	p^1		p^2, F	p^2, S, F	p^2, F	p^2, S, F	p^2, S
Marsh	p^1, S	p^1, S	p^1	p^2, F	p^2, S, F	p^2, F	p^2, S, F	p^2, S

Table 11 (Continued)

	Mega- inverts	Demersal fishes	Nektonic fishes
Polyhaline			
Subtidal			
Rock Bottom			
Bedrock	P^2, F	F	F
Rubble	P^2, F	F, S	F
Unconsolidated Bottom			
Cobble-Gravel	P^2, F	F	F
Sand	P^2, F	F, S	F
Mud	P^2, F	F, S	F
Aquatic Bed			
Rooted Vascular	P^2, F	S, F, R	S, F, R
Algal	P^2, F	S, F, R	S, F, R
Reef			
Worm	P^2, S, F	F	F
Mollusc	P^2, S, F	S, F, R	S, F, R
Intertidal			
Rock Bottom			
Bedrock	F	F	F
Rubble	F	F	F
Unconsolidated Bottom			
Cobble-Gravel	F	F	F
Sand	F	F	F
Mud	F	F	F
Aquatic Bed			
Rooted Vascular	P^2, S, F, R	S, F, R	S, F, R
Algal	P^2, S, F, R	S, F, R	S, F, R
Marsh	P^2, S, F, R	S, F, R	S, F, R

Table 11 (Continued)

	Shore Birds	NonShore Birds	Marine Reptiles	NonMarine Reptiles	Marine Mammals	NonMarine Mammals
Polyhaline						
Subtidal						
Rock Bottom						
Bedrock						
Rubble						
Unconsolidated Bottom						
Cobble-Gravel			F			
Sand			F		F	
Mud					F	
Aquatic Bed						
Rooted Vascular			F		F	
Algal			F		F	
Reef						
Worm			F			
Mollusc					F	
Intertidal						
Rock Bottom						
Bedrock	F	F	F			F
Rubble	F	F	F			F
Unconsolidated Bottom						
Cobble-Gravel	F	F	F			F
Sand	F	F	R			F
Mud	F	F				F
Aquatic Bed						
Rooted Vascular	F					
Algal	F	F				F, R
Marsh	F, R	F, R		F		F, R

Table 11 (Continued)

	Algae micro	Algae macro	Vascular plants	Meio- infauna	Meio- epifauna	Macro- infauna	Macro-Epifauna mobile	Macro-Epifauna attached
Mesohaline								
Subtidal								
Rock Bottom								
Bedrock	p^1	p^1			p^2, S		p^2, F	p^2, S
Rubble	p^1	p^1			p^2, S		p^2, F	p^2, S
Unconsolidated Bottom								
Cobble-Gravel	p^1	p^1		p^2, F			p^2, F	p^2, S
Sand	p^1	p^1		p^2, F	p^2, F	p^2, F	p^2, F	
Mud	p^1	p^1		p^2, F	p^2, F	p^2, F	p^2, F	
Aquatic Bed								
Rooted Vascular	p^1, S	p^1, S	p^1	p^2, F	p^2, S, F	p^2, F	p^2, S, F	p^2, S
Algal	p^1, S	p^1		p^2, F	p^2, S, F	p^2, F	p^2, S, F	p^2, S
Reef								
Worm					p^2, S, F		p^2, S, F	p^2, S
Mollusc	p^1			p^2, S, F	p^2, F	p^2, F	p^2, S, F	p^2, S
Intertidal								
Rock Bottom								
Bedrock	p^1	p^1			p^2, S		p^2, S, F	p^2, S
Rubble	p^1	p^1			p^2, S		p^2, S, F	p^2, S
Unconsolidated Bottom								
Cobble-Gravel	p^1	p^1		p^2, F	p^2, F	p^2, F	p^2, F	p^2, F
Sand	p^1	p^1		p^2, F	p^2, F	p^2, F	p^2, F	
Mud	p^1	p^1		p^2, F	p^2, F	p^2, F	p^2, F	
Aquatic Bed								
Rooted Vascular	p^1, S	p^1, S	p^1	p^2, F	p^2, S, F	p^2, F	p^2, S, F	p^2, S
Algal	p^1, S	p^1		p^2, F	p^2, S, F	p^2, F	p^2, S, F	p^2, S
Marsh	p^1, S	p^1, S	p^1	p^2, F	p^2, S, F	p^2, F	p^2, S, F	p^2, S

Table 11 (Continued)

	Mega-inverts	Demersal fishes	Nektonic fishes
Mesohaline			
Subtidal			
Rock Bottom			
Bedrock	P^2, F	F	F
Rubble	P^2, F	F, S	F
Unconsolidated Bottom			
Cobble-Gravel	P^2, F	F	F
Sand	P^2, F	F, S	F
Mud	P^2, F	F, S	F
Aquatic Bed			
Rooted Vascular	P^2, F	S, F, R	S, F, R
Algal	P^2, F	S, F, R	S, F, R
Reef			
Coral	P^2, S, F	S, F, R	S, F, R
Worm	P^2, S, F	F	F
Mollusc	P^2, S, F	S, F, R	S, F, R
Intertidal			
Rock Bottom			
Bedrock	F	F	F
Rubble	F	F	F
Unconsolidated Bottom			
Cobble-Gravel	F	F	F
Sand	F	F	F
Mud	F	F	F
Aquatic Bed			
Rooted Vascular	P^2, S, F, R	S, F, R	S, F, R
Algal	P^2, S, F, R	S, F, R	S, F, R
Marsh	P^2, S, F, R	S, F, R	S, F, R

Table 11 (Continued)

	Shore Birds	NonShore Birds	Marine Reptiles	NonMarine Reptiles	Marine Mammals	NonMarine Mammals
Mesohaline						
Subtidal						
Rock Bottom						
Bedrock						
Rubble						
Unconsolidated Bottom						
Cobble-Gravel						
Sand						
Mud						
Aquatic Bed						
Rooted Vascular						
Algal						
Reef						
Worm						
Mollusc						
Intertidal						
Rock Bottom						
Bedrock	F	F				F
Rubble	F	F				F
Unconsolidated Bottom						
Cobble-Gravel	F	F				F
Sand	F	F				F
Mud	F	F				F
Aquatic Bed						
Rooted Vascular	F					
Algal	F	F				F, R
Marsh	F, R	F, R		F		F, R

Table 11 (Continued)

	Algae micro	Algae macro	Vascular plants	Meio- infauna	Meio- epifauna	Macro- infauna	Macro-Epifauna mobile	Macro-Epifauna attached
Oligohaline								
Subtidal								
Rock Bottom								
Bedrock	p^1	p^1			p^2, S		p^2, F	p^2, S
Rubble	p^1	p^1			p^2, S		p^2, F	p^2, S
Unconsolidated Bottom								
Cobble-Gravel	p^1	p^1		p^2, F			p^2, F	p^2, S
Sand	p^1	p^1		p^2, F	p^2, F	p^2, F	p^2, F	
Mud	p^1	p^1		p^2, F	p^2, F	p^2, F	p^2, F	
Aquatic Bed								
Rooted Vascular	p^1, S	p^1, S	p^1	p^2, F	p^2, S, F	p^2, F	p^2, S, F	p^2, S
Algal	p^1, S	p^1		p^2, F	p^2, S, F	p^2, F	p^2, S, F	p^2, S
Reef								
Mollusc	p^1			p^2, F	p^2, S, F	p^2, F	p^2, S, F	p^2, S
Intertidal								
Rock Bottom								
Bedrock	p^1	p^1			p^2, S		p^2, S, F	p^2, S
Rubble	p^1	p^1			p^2, S		p^2, S, F	p^2, S
Unconsolidated Bottom								
Cobble-Gravel	p^1	p^1		p^2, F	p^2, F	p^2, F	p^2, F	p^2, F
Sand	p^1	p^1		p^2, F	p^2, F	p^2, F	p^2, F	
Mud	p^1	p^1		p^2, F	p^2, F	p^2, F	p^2, F	
Aquatic Bed								
Rooted Vascular	p^1, S	p^1, S	p^1	p^2, F	p^2, S, F	p^2, F	p^2, S, F	p^2, S
Algal	p^1, S	p^1		p^2, F	p^2, S, F	p^2, F	p^2, S, F	p^2, S
Marsh	p^1, S	p^1, S	p^1	p^2, F	p^2, S, F	p^2, F	p^2, S, F	p^2, S

Table 11 (Continued)

	Mega- inverts	Demersal fishes	Nektonic fishes
Oligohaline			
Subtidal			
Rock Bottom			
Bedrock	P^2, F	F	F
Rubble	P^2, F	F, S	F
Unconsolidated Bottom			
Cobble-Gravel	P^2, F	F	F
Sand	P^2, F	F, S	F
Mud	P^2, F	F, S	F
Aquatic Bed			
Rooted Vascular	P^2, F	S, F, R	S, F, R
Algal	P^2, F	S, F, R	S, F, R
Reef			
Mollusc	P^2, S, F	S, F, R	S, F, R
Intertidal			
Rock Bottom			
Bedrock	F	F	F
Rubble	F	F	F
Unconsolidated Bottom			
Cobble-Gravel	F	F	F
Sand	F	F	F
Mud	F	F	F
Aquatic Bed			
Rooted Vascular	P^2, S, F, R	S, F, R	S, F, R
Algal	P^2, S, F, R	S, F, R	S, F, R
Marsh	P^2, S, F, R	S, F, R	S, F, R

Table 11 (Continued)

	Shore Birds	NonShore Birds	Marine Reptiles	NonMarine Reptiles	Marine Mammals	NonMarine Mammals
Oligohaline						
Subtidal						
Rock Bottom						
Bedrock						
Rubble						
Unconsolidated Bottom						
Cobble-Gravel						
Sand						
Mud						
Aquatic Bed						
Rooted Vascular						
Algal						
Reef						
Coral						
Worm						
Mollusc						
Intertidal						
Rock Bottom						
Bedrock		F				F
Rubble		F				F
Unconsolidated Bottom						
Cobble-Gravel		F				F
Sand		F				F
Mud		F				F
Aquatic Bed						
Rooted Vascular						
Algal		F				F, R
Marsh		F, R		F		F, R

Table 11 (Continued)

	Algae micro	Algae macro	Vascular plants	Meio- infauna	Meio- epifauna	Macro- infauna	Macro-Epifauna mobile	Macro-Epifauna attached
Tidal Riverine								
Subtidal								
Rock Bottom								
Bedrock	p^1	p^1			p^2, S		p^2, F	p^2, S
Rubble	p^1	p^1			p^2, S		p^2, F	p^2, S
Unconsolidated Bottom								
Cobble-Gravel	p^1	p^1		p^2, F			p^2, F	p^2, S
Sand	p^1	p^1		p^2, F	p^2, F	p^2, F	p^2, F	
Mud	p^1	p^1		p^2, F	p^2, F	p^2, F	p^2, F	
Aquatic Bed								
Rooted Vascular	p^1, S	p^1, S	p^1	p^2, F	p^2, S, F	p^2, F	p^2, S, F	p^2, S
Intertidal								
Rock Bottom								
Bedrock	p^1	p^1			p^2, S		p^2, S, F	p^2, S
Rubble	p^1	p^1			p^2, S		p^2, S, F	p^2, S
Unconsolidated Bottom								
Cobble-Gravel	p^1	p^1		p^2, F	p^2, F	p^2, F	p^2, F	p^2, F
Sand	p^1	p^1		p^2, F	p^2, F	p^2, F	p^2, F	
Mud	p^1	p^1		p^2, F	p^2, F	p^2, F	p^2, F	
Aquatic Bed								
Rooted Vascular	p^1, S	p^1, S	p^1	p^2, F	p^2, S, F	p^2, F	p^2, S, F	p^2, S
Marsh	p^1, S	p^1, S	p^1	p^2, F	p^2, S, F	p^2, F	p^2, S, F	p^2, S

Table 11 (Continued)

	Mega- inverts	Demersal fishes	Nektonic fishes
Tidal Riverine			
Subtidal			
Rock Bottom			
Bedrock	P^2, F	F	F
Rubble	P^2, F	F, S	F
Unconsolidated Bottom			
Cobble-Gravel	P^2, F	F	F
Sand	P^2, F	F, S	F
Mud	P^2, F	F, S	F
Aquatic Bed			
Rooted Vascular	P^2, F	S, F, R	S, F, R
Intertidal			
Rock Bottom			
Bedrock	F	F	F
Rubble	F	F	F
Unconsolidated Bottom			
Cobble-Gravel	F	F	F
Sand	F	F	F
Mud	F	F	F
Aquatic Bed			
Rooted Vascular	P^2, S, F, R	S, F, R	S, F, R
Marsh	P^2, S, F, R	S, F, R	S, F, R

Table 11 (Continued)

	Shore Birds	NonShore Birds	Marine Reptiles	NonMarine Reptiles	Marine Mammals	NonMarine Mammals
Tidal Riverine						
Subtidal						
Rock Bottom						
Bedrock						
Rubble						
Unconsolidated Bottom						
Cobble-Gravel						
Sand						
Mud						
Aquatic Bed						
Rooted Vascular						
Intertidal						
Rock Bottom						
Bedrock		F				F
Rubble		F				F
Unconsolidated Bottom						
Cobble-Gravel		F				F
Sand		F				F
Mud		F				F
Aquatic Bed						
Rooted Vascular						
Marsh		F, R		F		F, R

Table 11 (Concluded)

Modifiers	
Environmental Energy	High - (e.g., Exposed to Wave or Current Action). Moderate - (e.g., Semiexposed to Wave or Current Action). Low - (e.g., Protected).
Tidal Inundation	Regularly flooded. Irregularly flooded.
Artificial	Jetty. Diked. Marsh. Agriculture. Aquaculture or Mariculture.
Special Salinity	Hypersaline.
Special Substrate	Organic. Sediment Mixtures.

Table 12
Anywhere Bay Habitat Structure and Functional Attribute Matrix

Habitat	Algae micro	Algae macro	Meio- infauna	Meio- epifauna	Macro-Infauna	Macro-Epifaunal mobile	Macro-Epifaunal attached	Mega-inverts
Marine Subtidal Sand	P^1	P^1	P^2, F	P^2, F	P^2, F	P^2, F		P^2, F
Intertidal Rubble	P^1	P^1		P^2, S		P^2, S, F	P^2, S	F, S

Habitat	Demersal fishes	Nektonic fishes	Shore Birds	NonShore Birds	Marine Reptiles	Marine Mammals	NonMarine Mammals
Marine Subtidal Sand	F, S	F			F	F	
Intertidal Rubble	F, S	F	F	F	F		F

Habitat	Algae micro	Algae macro	Vascular plants	Meio- infauna	Meio- epifauna	Macro-infauna	Macro-Epifauna mobile	Macro-Epifauna attached
Polyhaline Subtidal Sand	P^1	P^1		P^2, F	P^2, F	P^2, F	P^2, F	
Rooted Vascular (Grassbed)	P^1, S	P^1, S	P^1	P^2, F	P^2, S, F	P^2, F	P^2, S, F	P^2, S
Intertidal Mud	P^1	P^1		P^2, F	P^2, F	P^2, F	P^2, F	
Marsh	P^1, S	P^1, S	P^1	P^2, F	P^2, S, F	P^2, F	P^2, S, F	P^2, S

Habitat	Mega-Inverts	Demersal fishes	Nektonic fishes	Shore Birds	NonShore Birds	Marine Reptiles	NonMarine Reptiles
Polyhaline Subtidal Sand	P^2, F	F, S	F			F	
Rooted Vascular (Grassbed)	P^2, F	S, F, R	S, F, R		F		F
Intertidal Mud	F	F	F	F	F		
Marsh	P^2, S, F, R	S, F, R	S, F, R	F, R	F, R		F

(Continued)

Note: P^1 = Primary Productivity. P^2 = Secondary Productivity. S = Structure (Substrate, Refuge, etc.). F = Feeding. R = Reproduction and Development.

Table 12 (Concluded)

	Marine Mammals	NonMarine Mammals
Polyhaline Subtidal Sand	F	
Rooted Vascular (GrassBed)		
Intertidal Mud		F
Marsh		F, R

	Algae micro	Algae macro	Vascular plants	Meio- infauna	Meio- epifauna	Macro- infauna	Macro-Epifauna mobile	Macro-Epifauna attached
Mesohaline Subtidal Mud	P^1	P^1		P^2, F	P^2, F	P^2, F	P^2, F	
Marsh	P^1, S	P^1, S	P^1	P^2, F	P^2, S, F	P^2; F	P^2, S, F	P^2, S

	Mega- inverts	Demersal fishes	Nektonic fishes	Shore Birds	NonShore Birds	NonMarine Reptiles	NonMarine Mammals
Mesohaline Subtidal Mud	P^2, F	F, S	F				
Marsh	P^2, S, F, R	S, F, R	S, F, R	F, R	F, R	F	F, R

	Algae micro	Algae macro	Vascular plants	Meio- infauna	Meio- epifauna	Macro- infauna	Macro-Epifauna mobile	Macro-Epifauna attached
Oligohaline Marsh	P^1, S	P^1, S	P^1	P^2, F	P^2, S, F	P^2, F	P^2, S, F	P^2, S

	Mega- inverts	Demersal fishes	Nektonic fishes	NonShore Birds	NonMarine Reptiles	NonMarine Mammals
Oligohaline Marsh	P^2, S, F, R	S, F, R	S, F, R	F, R	F	F, R

Table 13
Anywhere Bay Critical Habitat/Attribute Matrix

Habitat	Algae macro-	Macro-infauna	Macro-Epifauna mobile	Macro-Epifauna attached	Mega-inverts	Demersal fishes	Nektonic fishes
Marine Subtidal Sand		p^2	p^2		p^2, F	F	F
Intertidal Rubble	p^1		p^2	p^2, S	F	F	F

Habitat	Algae micro	Algae macro	Vascular plants	Macro-infauna	Macro-Epifauna mobile	Macro-Epifauna attached	Mega-inverts	Demersal fishes	Nektonic fishes
Polyhaline Subtidal Sand				p^2, F	p^2, F		p^2, F	F	F
Grass Bed	p^1	p^1	p^1	p^2, F	p^2, F	p^2, S	p^2, F	F, R	F, R
Intertidal Mud	p^1			p^2, F	p^2, F		F	F	F
Marsh	p^1	p^1	p^1	p^2, F	p^2, F	p^2, S	p^2, F, R	F, R	F, R

	ShoreBirds
Polyhaline Subtidal Sand	
Grass Bed	
Intertidal Mud	F
Marsh	F, R

	Algae micro	Algae macro	Vascular plants	Macro-infauna	Macro-Epifauna mobile	Macro-Epifauna attached	Mega-inverts	Demersal fishes	Nektonic fishes	Shore birds
Mesohaline Mud		p^1	p^1		p^2, F	p^2	p^2	F	F	F
Marsh		p^1	p^1	p^1	p^2, F	p^2	p^2, S	p^2, F, R	F, R	F, R

(Continued)

Table 13 (Concluded)

Habitat		Vascular plants	Macro-infauna	Macro-Epifauna mobile	Macro-Epifauna attached	Mega-inverts	Demersal fishes	Nektonic fishes
Oligohaline Marsh	I	P^1	P^2, F	P^2, F	P^2, S	P^2, F, R	F, R	F, R

Habitat		NonShore Birds	NonMarine Reptiles	NonMarine Mammals
Oligohaline Marsh	I	F, R	F	F, R

Table 14
Coastal Biogeographic Provinces of the United States[1]

Province (Alternative Terminology)	Approximate Geographic Boundaries
Arcadian	Southern Greenland to Cape Cod.
Virginian	Cape Cod to Cape Hatteras.
Carolinian	Cape Hatteras to Cape Canaveral.
West Indian (Floridian)	Cape Canaveral to Cedar Key, FL.
Louisianian	Cedar Key, FL, to Port Aransas, TX.
Californian	Cape Mendocino to Mexico.
Columbian (Oregonian)	Cape Mendocino to Vancouver Island.
Fjords (Aleutian)	Vancouver Island to tip of Aleutian Island Arc.
Pacific Arctic (Alaskan)	Coast of Alaska not including Aleutian Island Arc.
Pacific Insular (Hawaiian)	Hawaii

[1] After Ray (1975) and Bailey (1976, 1978).

Table 15
Regionally Adjusted Estimates for Anywhere Bay Habitat/Attribute Values

Attribute	Marine		Polyhaline				Mesohaline		Oligohaline
	Sand	Rocky	Sand	Grass	Mud	Marsh	Mud	Marsh	Marsh
MicroAlgae P^1	-	-	-	100	100	100	100	100	100
MacroAlgae P^1	-	75	-	100	-	80	100	80	100
Vascular Plant P^1	-	-	-	100	-	100	-	100	100
Macroinfaunal P^2	100	-	75	100	100 (A) 50 (B)	75	100	75	25
Mobile Epifaunal P^2	-	100	100	100	100	100	100	100	75
Mobile Epifaunal S	-	100	-	100	-	100	-	100	100
Attached Epifaunal P^2	-	75	-	100	-	100	-	100	60
Attached Epifaunal S	-	100	-	100	-	100	-	100	60
Megainvertebrate P^2	100	100	100	100	-	100	-	100	100
Megainvertebrate F	100	75	75	100	-	100	-	100	100
Megainvertebrate S	-	100	-	100	-	100	-	70	60
Demersal Fish F	100	-	75	100	100 (A) 50 (B)	100	100	75	25
Demersal Fish R	-	-	-	100	-	100	-	100	100
Nektonic Fish F	100	75	75	100	100	100	100	100	100
Nektonic Fish R	-	-	-	100	-	100	-	100	100
Shorebird F	-	-	-	-	100(A) 50(B)	50	100	100	25
Shorebird R	-	-	-	-	-	100	-	100	100
NonShorebird F	-	-	-	-	100(A) 50(B)	50	100	100	25
Nonshorebird R	-	-	-	-	-	100	-	100	100
NonMarine Reptile F	-	-	-	-	-	-	-	-	100
NonMarine Mammal F	-	-	-	-	-	-	-	-	100
NonMarine Mammal R	-	-	-	-	-	-	-	-	100

Note: P^1 = Primary Productivity. F = Feeding. P^2 = Secondary Productivity. R = Reproduction and Development. S = Structure.

Table 16
Values for Anywhere Bay Area Habitat/Attribute Before Project

Attribute	Marine		Polyhaline				Mesohaline		Oligohaline
	Sand	Rocky	Sand	Grass	Mud	Marsh	Mud	Marsh	Marsh
MicroAlgae P^1	-	-	-	250	100	800	100	400	800
MacroAlgae P^1	-	45	-	250	-	640	100	320	800
Vascular Plant P^1	-	-	-	250	-	800	-	400	800
Macroinfaunal P^2	2000	-	1880	250	50 (A) 25 (B)	640	100	300	200
Mobile Epifaunal P^2	-	60	2500	250	100	800	100	400	600
Mobile Epifaunal S	-	60	-	250	-	800	-	400	800
Attached Epifaunal P^2	-	45	-	250	-	800	-	400	480
Attached Epifaunal S	-	60	-	250	-	800	-	400	480
Megainvertebrate P^2	2000	60	2500	250	-	800	-	400	800
Megainvertebrate F	2000	45	1880	250	-	800	-	400	800
Megainvertebrate S	-	60	-	250	-	800	-	280	480
Demersal Fish F	2000	-	1880	250	50 (A) 25 (B)	800	100	300	200
Demersal Fish R	-	-	-	250	-	800	-	400	800
Nektonic Fish F	2000	45	1880	250	100	800	100	400	800
Nektonic Fish R	-	-	-	250	-	800	-	400	800
Shorebird F	-	-	-	-	50 (A) 25 (B)	400	100	400	200
Shorebird R	-	-	-	-	-	800	-	400	800
NonShorebird F	-	-	-	-	50 (A) 25 (B)	400	100	400	200
Nonshorebird R	-	-	-	-	-	800	-	400	800
NonMarine Reptile F	-	-	-	-	-	-	-	-	800
NonMarine Mammal F	-	-	-	-	-	-	-	-	800
NonMarine Mammal R	-	-	-	-	-	-	-	-	800

Table 17
Values for Anywhere Bay Habitat/Attribute 5 Years After Project

Attribute	Marine		Polyhaline					Mesohaline		Oligohaline	
	Sand	Rocky	Sand	Grass	Grass Constructed	Mud	Marsh	Mud	Marsh	Mud	Marsh
MicroAlgae P[1]	-	-	-	250	50	100	800	100	400	-	0
MacroAlgae P[1]	-	45	-	250	0	-	640	100	320	-	0
Vascular Plant P[1]	-	-	-	250	100	-	800	-	400	-	0
Macroinfaunal P[2]	2000	-	1800	250	75	50(A) 25(B)	640	100	300	20	0
Mobile Epifaunal P[2]	-	60	2400	250	100	100	800	100	400	20	0
Mobile Epifaunal S	-	60	-	250	100	-	800	-	400	-	0
Attached Epifaunal P[2]	-	45	-	250	100	-	800	-	400	-	0
Attached Epifaunal S	-	60	-	250	100	-	800	-	400	-	0
Megainvertebrate P[2]	2000	60	2400	250	75	-	800	-	400	20	0
Megainvertebrate F	2000	45	1800	250	100	-	800	-	400	20	0
Megainvertebrate S	-	60	-	250	100	-	800	-	280	20	0
Demersal Fish F	2000	-	1800	250	75	50(A) 25(B)	800	100	300	20	0
Demersal Fish R	-	-	-	250	100	-	800	-	400	-	0
Nektonic Fish F	2000	45	1800	250	75	100	800	100	400	20	0
Nektonic Fish R	-	-	-	250	100	-	800	-	400	-	0
Shorebird F	-	-	-	-	-	50(A) 25(B)	400	100	400	-	0
Shorebird R	-	-	-	-	-	-	800	-	400	-	0
NonShorebird F	-	-	-	-	- 25(B)	50(A)	400	100	400	-	0
Nonshorebird R	-	-	-	-	-	-	800	-	400	-	0
NonMarine Reptile F	-	-	-	-	-	-	-	-	-	-	0
NonMarine Mammal F	-	-	-	-	-	-	-	-	-	-	0
NonMarine Mammal R	-	-	-	-	-	-	-	-	-	-	0

Table 18
Values for Anywhere Bay Area Habitat/Attribute 25 Years After Project

Attribute	Marine		Polyhaline					Mesohaline		Oligohaline	
	Sand	Rocky	Sand	Grass	Grass Constructed	Mud	Marsh	Mud	Marsh	Mud	Marsh
MicroAlgae P[1]	-	-	-	250	100	100	800	40	400	200	0
MacroAlgae P[1]	-	60	-	250	100	-	640	200	320	-	0
Vascular Plant P[1]	-	-	-	250	100	-	800	-	400	-	0
Macroinfaunal P[2]	2000	-	1800	250	100	50(A) 25(B)	640	150	300	200	0
Mobile Epifaunal P[2]	-	60	2400	250	100	100	800	100	400	0	0
Mobile Epifaunal S	-	60	-	250	100	-	800	-	400	-	0
Attached Epifaunal P[2]	-	60	-	250	100	-	800	-	400	-	0
Attached Epifaunal S	-	60	-	250	100	-	800	-	400	-	0
Megainvertebrate P[2]	2000	60	2400	250	100	-	800	-	400	0	0
Megainvertebrate F	2000	60	1800	250	100	-	800	-	400	0	0
Megainvertebrate S	-	60	-	250	100	-	800	-	280	0	0
Demersal Fish F	2000	-	1800	250	100	50(A) 25(B)	800	0	300	0	0
Demersal Fish R	-	-	-	250	100	-	800	-	400	-	0
Nektonic Fish F	2000	60	1800	250	100	100	800	0	400	0	0
Nektonic Fish R	-	-	-	250	100	-	800	-	400	-	0
Shorebird F	-	-	-	-	-	50(A) 25(B)	400	0	400	0	0
Shorebird R	-	-	-	-	-	-	800	-	400	-	0
NonShorebird F	-	-	-	-		50(A) 25(B)	400	0	400	-	0
Nonshorebird R	-	-	-	-	-	-	800	-	400	-	0
NonMarine Reptile F	-	-	-	-	-	-	-	-	-	-	0
NonMarine Mammal F	-	-	-	-	-	-	-	-	-	-	0
NonMarine Mammal R	-	-	-	-	-	-	-	-	-	-	0

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13. ABSTRACT *(Maximum 200 words)*

Construction and maintenance work in coastal areas can result in damage to estuarine and marine habitats. Mitigation for these impacts often involves the construction of an "out-of-kind" habitat or the sacrifice of a different type of habitat. At the present time, there are no effective methods for comparing the ecological importance of different types of coastal habitats or the cumulative impact of changes in the abundance and proportions of different habitats on coastal ecosystems. This report describes a conceptual framework for making ecologically based comparisons of coastal habitats. The framework is an inventory and accounting procedure in which the contribution of each habitat is estimated from measures of habitat area and habitat functional attributes. This document represents a discussion of the framework and how it might realistically be applied.

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